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# FOREST CONTROL

## by CONTINUOUS INVENTORY

"Today I have grown taller from walking  
with the trees."

...Karle Wilson

Milwaukee, Wis. Sept. 1958 No. 54

### FORMULAS AND CONVERTORS FOR PUNCH CARD COMPUTING INDUSTRIAL C.F.I. CASES

We have at last brought together all of the common formulas and converting factors used in the machine computation of industrial C.F.I. cases. Each of the attached sheets gives a completed example covering each of the formulas and convertors. These examples include:

1. Per acre reductions
2. Total expansions  
Using per acre value times expanded area  
Using expansion factor times volume in sample
3. Stock and stand tables  
Per acre values by the reciprocal method  
Total forest values by the expansion factor  
method
4. Volume per tree with the Residual Cubic Foot  
Volume formula
5. Volume per tree with the cord C.F.I. formula
6. Volume per tree of body wood in cubic feet
7. Converting factors:  
International to Scribner  
For limbwood in cubic feet  
For top and body wood combined in cubic feet  
For top wood in cubic feet  
Cubic feet to cords

Since these formulas are standard for C.F.I. cases it is important to save the machine specifications and wiring diagrams for repeated use.

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STANDARD SYMBOLS FOR MACHINE CALCULATIONS WITH PUNCH CARD ACCOUNTING  
INDUSTRIAL C.F.I. CASES

| <u>Maximum<br/>Decimals</u> |           |  |
|-----------------------------|-----------|--|
| r                           | —         | Reciprocal   |
| Pa                          | —         | Per acre values  |
| Sp                          | x.xx      | Species correction factor  |
| So                          | x.xx      | Soundness correction factor  |
| L                           | xx.       | Usable length of each tree   |
| 5                           | x.        | Per acre factor for fifth acre plots                                 |
| 7                           | x.        | Per acre factor for seventh acre plots                               |
| Ea                          | — .xxxx   | Expanded area or (Ae x N)  |
| X                           | —         | Expanded volume, tree count or basal area                            |
| V                           | —         | Volume   |
| V1                          | xxxx.x    | Volume per tree, International, Board Feet                           |
| Vs                          | xxxx.x    | Volume per tree, Scribner, Board Feet                                |
| Vpcu                        | xxx.xx    | Volume per tree, pulpwood, cubic feet                                |
| Vped                        | x.xxx     | Volume per tree, pulpwood, cords                                     |
| Vlcu                        | xx.xx     | Volume per tree, limbwood, cubic feet                                |
| Vtcu                        | xx.xx     | Volume per tree, topwood, cubic feet                                 |
| Vbcu                        | xxx.xx    | Volume per tree, bodywood, cubic feet                                |
| Vled                        | .xxx      | Volume per tree, limbwood, cords                                     |
| Vted                        | .xxx      | Volume per tree, topwood, cords                                      |
| Vbcd                        | x.xxx     | Volume per tree, bodywood, cords                                     |
| Na                          | —         | Number of sample plots measured in each area breakdown               |
| N                           | —         | Number of sample plots measured on total forest                      |
| T                           | —         | Volume, tree count or basal area in sample                           |
| Cs                          | .xxx      | Converting factor; International to Scribner log scale               |
| Ct                          | .xxxx     | Converting factor; top wood above sawlog length                      |
| Cl                          | .xxx      | Converting factor; limb wood above top wood                          |
| Cb                          | .xxxxx    | Converting factor; sawlogs 8" top, to cu. ft. 4" top                 |
| A                           | — .xxxx   | Area, total forest   |
| Ae                          | xxx.xxxx  | Area expander; area of forest represented by each plot or<br>(A + N) |
| Af                          | xxxx.xxxx | Area expansion factor for volume, basal area or tree count           |
| As                          | —         | Area of measured sample or plot acres (N + 5) or (N + 7)             |
| a                           | —         | Individual tree residual volume factor                               |
| b                           | — →       | Individual tree length multiplying factor                            |
| 1<br>79                     | .xxxxx    | Converting factor; cubic feet to cords. The reciprocal<br>is .01266  |

Definitions:

Limb wood - Pieces over 4" long with a minimum 4" top d.i.b. above the top wood.  
 Top wood - 100 inch pulp sticks to a minimum 4" D.I.B. above the bodywood  
 Body wood - The sawlog portion of the tree

MACHINE CALCULATING THE REDUCTION TO PER ACRE VALUES  
INDUSTRIAL C.F.I. CASES

THE FORMULA

$$Pa = T \left( \frac{5}{Na} \right)$$

IN WHICH

Pa = Per acre value

xx . xxxx

5 = Per acre factor for fifth acre plots

x .

T = Number of cords\* in the sample

xxx . xxx

Na = Number of sample plots measured

xx .

THE EXAMPLE

5 = Per acre factor for fifth acre plots

T = 175.566 cords

Na = 25. plots

THE SOLUTION

$$Pa = 175.566 \left( \frac{5}{25} \right)$$

Pa = 35.1132 cords

The average Industrial C.F.I.  
case uses this formula on at  
least 500 separate calculations

|                |          |
|----------------|----------|
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\* Cubic feet and board feet can also be computed

MACHINE CALCULATING THE TOTAL EXPANSION USING PER ACRE VALUES  
INDUSTRIAL C.F.I. CASES

THE FORMULA

$$X = (Pa)(Ea)$$

IN WHICH

X = Expanded volume  
Pa = Per acre value in cords\*  
Ea = Expanded area

DECIMALS

xxxxx .  
xx . xxxx  
xxxx . xxxx

THE EXAMPLE

Pa = 35.1132 cords per acre  
Ea = 1000.1241 acres

THE SOLUTION

$$X = (35.1132)(1000.1241)$$

X = 35,118. cords

The average Industrial C.F.I. case uses this formula, or the one on Page 4, on two to three hundred volume expansions

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\* Cubic feet and board feet can also be computed

MACHINE CALCULATING THE TOTAL EXPANSION USING THE EXPANSION FACTOR  
INDUSTRIAL C.F.I. CASES

THE FORMULA

$$X = (T) (Af)$$

IN WHICH

X = Expanded volume

DECIMALS

xxxxx .

Af = Area expansion factor

xxx . xxxx

T = Number of cords\* in the sample

xxx . xxx

Ea = Expanded area, 1000.1241 acres

xxxxx . xxxx

As = Plot acres or area of sample  $\frac{25}{5}$

x . x

THE EXAMPLE

Af = Ea divided by As or  $1000.1241 + 5 = 200.0248$

T = 175.566 cords

THE SOLUTION

$$X = (175.566) (200.0248)$$

$$X = 35,118. \text{ cords}$$

The average Industrial C.F.I. case uses this formula, or the one on Page 3, on two to three hundred volume expansions

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\* Cubic feet and board feet can also be computed

MACHINE CALCULATING THE REDUCTION TO PER ACRE AND THE TOTAL EXPANSION IN STOCK AND STAND TABLES

INDUSTRIAL C.F.I. CASES

THE FORMULA

$$Pa = (T) (r)$$

$$X = (T) (Af)$$

IN WHICH

Pa = Per acre value

xx . xxxx

X = Expanded volume

xxxxx .

T = Number of cords\* in the sample

xxx . xxx

Af = Area expansion factor for cords

xxx . xxxx

r = Reciprocal of acres in sample

. xxxx

THE EXAMPLE

T = 175.566 cords

Af = 200.0248 factor

r = .2000 reciprocal

THE SOLUTION

$$Pa = (175.566) (.2000)$$

$$Pa = 35.1132 \text{ cords}$$

$$X = (175.566) * (200.0248)$$

$$X = 35,118. \text{ cords}$$

Industrial C.F.I. cases prepare 10 to 50 stock and stand tables in 2" DBH classes for about 12 species. This requires 6,000 to 30,000 separate per-acre calculations using this formula. The answers are given in cords, board feet, tree count and basal area. There are an additional 2,000 to 10,000 separate calculations for the total expansion of board foot and cord volumes.

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\* Cubic feet and board feet can also be computed

MACHINE CALCULATING THE PULPWOOD VOLUME OF INDIVIDUAL TREES IN  
CUBIC FEET AND CORDS

THE RESIDUAL VOLUME FORMULA IN CUBIC FEET AND CORDS

$$V_p = [a + (b \times L)] (S_p) (S_o) (r)$$

IN WHICH

DECIMALS

$V_p$  = Pulpwood volume per tree, net  
 $V_{pcu}$  = Pulp volume per tree in cubic feet, net  
 $V_{ped}$  = Pulp volume per tree in cords, net

xx . xx  
· xxx

a = Residual volume factor  
b = Length multiplying factor  
L = Usable length of each tree  
S<sub>p</sub> = Species correction factor  
S<sub>o</sub> = Soundness correction factor  
r = Cubic foot to cord converting reciprocal for  $\frac{1}{79}$

xx . xxx  
x . xxxxx  
xx .  
x . xx  
x . xx  
· xxxxx

THE EXAMPLE FOR A RED OAK TREE

a = .699 factor  
b = .18927 factor  
S<sub>p</sub> = 1.00 factor  
S<sub>o</sub> = 0.86 factor  
r = .01266 reciprocal

DBH = 8.0 inches  
L = 32. feet

THE SOLUTION

$$V_p = [0.699 + (0.18927 \times 32)] (1.00) (0.86) (.01266)$$

$V_{pcu}$  = 6.76 cubic feet gross  
 $V_{pcu}$  = 5.81 cubic feet net  
 $V_{ped}$  = .074 cords net

The average Industrial C.F.I. case uses this formula on 2,000 to 10,000 pulpwood trees

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Note: Tables of Residual Volume factors to be published soon in newsletter

MACHINE CALCULATING THE BOARD FOOT VOLUME OF INDIVIDUAL TREES  
INTERNATIONAL AND SCRIBNER LOG SCALE  
INDUSTRIAL C.F.I. CASES

THE C.F.I. FORMULA IN BOARD FEET

$$Vs = [a + (b \times L)] (Sp) (So) (Cs)$$

IN WHICH

DECIMALS

$V_i$  = Volume per tree in board feet International \*

XXX . X

$V_s$  = Volume per tree in board feet Scribner \*

XXX . X

a = Volume factor

XX . XX

b = Length multiplying factor

X . XX

L = Usable length of each tree

XX .

Sp = Species correction factor

X . XX

So = Soundness correction factor

X . XX

Cs = International to Scribner converting factor

. XXX

THE EXAMPLE FOR A RED OAK TREE

a = 28.16 factor  
 b = 6.55 factor  
 Sp = 1.04 factor  
 So = 0.97 factor  
 Cs = .894 factor

} See Newsletter No. 6, 9/1954

DBH = 18.0 inches  
 L = 32. feet

THE SOLUTION

THE SOLUTION

$$Vs = [28.16 + (6.55 \times 32)] (1.04) (0.97) (.894)$$

$V_i$  = 247.3 board feet gross International

$V_i$  = 239.9 board feet net International

$V_s$  = 214.5 board feet net Scribner

The average Industrial C.F.I.  
 case uses this formula on 2,000  
 to 10,000 sawlog trees.

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\* Cubic feet and cords can also be computed

Note: Tables of converting factor to be published in future newsletters

# MACHINE CALCULATING THE CUBIC FOOT VOLUME OF THE SAWLOG SECTIONS OF TREES (BODYWOOD)

## INDUSTRIAL C.F.I. CASES

### THE FORMULA FOR BODYWOOD

$$V_{bcu} = [a + (b \times L)] (Sp) (So)$$

#### IN WHICH

$V_{bcu}$  = Bodywood volume per tree in cubic feet

#### DECIMALS

xx . xx

a = Residual volume factor \*\*

xx . xxx

b = Length multiplying factor \*\*

x . xxx

L = Usable length of each tree, sawlogs (bodywood)

xx .

Sp = Species correction factor

x . xx

So = Soundness correction factor

x . xxx

### THE EXAMPLE FOR A RED OAK TREE

a = 11.600 factor

b = 1.333 factor

Sp = 1.04 factor

So = 0.93 factor

DBH = 22.0 inches

L = 30. feet

### THE SOLUTION

$$V_{bcu} = [11.600 + (1.333 \times 30)] (1.04) (0.93)$$

$$V_{bcu} = 53.65 \text{ cu. ft. (gross)}$$

$$V_{bcu} = 49.89 \text{ cu. ft. (net)}$$

The average Industrial C.F.I. case might use this formula on 5,000 to 10,000 trees.

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\*\* From Lake States Forest Experiment Station, University Farm,  
St. Paul, Minnesota, Technical Note 382

NOTE: Tables of residual volume, length multiplying and converting factors to be published in future newsletters.

MACHINE CALCULATING THE LIMB WOOD VOLUME OF INDIVIDUAL TREES

IN CUBIC FEET AND CORDS

INDUSTRIAL C.F.I. CASES

THE FORMULA FOR LIMB WOOD

$$V_l = (V_i) (Sp) (Cl) (r)$$

IN WHICH

DECIMALS

|                |   |                  |   |
|----------------|---|------------------|---|
| V <sub>l</sub> | = Limb wood volume per tree in cubic feet or cords    | cu. ft.<br>cords | xx . xx<br>. xxx<br>xxx . x<br>. xxxx<br>x . xx |
| V <sub>i</sub> | = Volume per tree in board feet, International, gross |                  |   |
| C <sub>l</sub> | = Converting factor, limb wood above top wood         |                  |   |
| S <sub>p</sub> | = Species correction factor                           |                  |   |
| r              | = Cubic foot to cord converting reciprocal for        | —<br>79          | — — . xxxxx                                     |

THE EXAMPLE FOR AN ELM TREE

V<sub>i</sub> = 104.8      board feet

S<sub>p</sub> = 1.05      factor

C<sub>l</sub> = .0425      factor

r = .01266      reciprocal

DBH = 14.0      inches

L<sub>s</sub> = 24.      feet (sawlogs)

THE SOLUTION

$$V_l = (104.8) (1.05) (.0425) (.01266)$$

$$V_{lcu} = 4.68 \text{ cubic feet (net)}$$

$$V_{lcd} = .059 \text{ cords (net)}$$

The average Industrial C.F.I. case might use this formula on 5,000 to 10,000 sawtimber trees. Individual tree values are not reliable but totals for groups of trees give a roughly reliable answer on the cubic feet of wood available in limbs. Converting factors are based on usable length classes in two-foot intervals as limb wood volume is not appreciably affected by tree diameter.

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NOTE: Tables of converting factors to be published in future newsletters.

MACHINE CALCULATING THE TOP AND BODY WOOD OF SAWLOG TREES IN CUBIC FEET  
USING CONVERTERS FROM GROSS INTERNATIONAL BOARD FOOT VOLUME

INDUSTRIAL C.F.I. CASES

THE FORMULA FOR TOP AND BODY WOOD

$$Vpcu = (Vi) (Sp) (Cb) (So)$$

IN WHICH

DECIMALS

Vpcu = Pulp volume per tree in cu. ft., net

xx . xx

Vi = Volume per tree in board feet, International, gross

xxx . x

Sp = Species correction factor

x . xx

Cb = Bd. ft. to Cu. ft. converter

. xxxxx

So = Soundness correction factor

x . xx

THE EXAMPLE FOR A RED OAK TREE

Vi = 343.0 board feet

Sp = 1.04 factor

Cb = .15025 factor

So = 0.93 factor

DBH = 22.0 inches

L = 30. feet (sawlogs)

THE SOLUTION

$$Vpcu = (343.0) (1.04) (.15025) (0.93)$$

$$Vpcu = 53.59 \text{ gross cu. ft.}$$

$$Vpcu = 49.84 \text{ net cu. ft.}$$

The average Industrial case might  
use this formula on 5,000 to 10,000  
trees.

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NOTE: Tables of converting factors to be published in future newsletters.

MACHINE CALCULATING THE TOP WOOD OF INDIVIDUAL SAWLOG TREES IN CUBIC FEET AND CORDS

INDUSTRIAL C.F.I. CASES

THE FORMULA FOR TOP WOOD

$$V_t = (V_i) (S_p) (C_t) (r)$$

IN WHICH

|                  |   | <u>DECIMALS</u> |
|------------------|---|-----------------|
| V <sub>t</sub>   | = Top wood volume per tree, net                               | x . xx          |
| V <sub>tcu</sub> | = Top wood volume per tree in cubic feet, net                 | x . xx          |
| V <sub>tcd</sub> | = Top wood volume per tree in cords, net                      | . xxxx          |
| V <sub>i</sub>   | = Volume per tree in board feet, International, gross         | xxx . x         |
| C <sub>t</sub>   | = Converting factor - top wood above sawlog length            | . xxxx          |
| S <sub>p</sub>   | = Species correction factor                                   | x . xx          |
| r                | = Cubic foot to cord converting reciprocal for $\frac{1}{79}$ | . xxxx          |

THE EXAMPLE FOR A RED OAK TREE

|                |          |                |
|----------------|----------|----------------|
| V <sub>i</sub> | = 237.8  | board feet     |
| S <sub>p</sub> | = 1.05   | factor         |
| C <sub>t</sub> | = .0245  | factor         |
| r              | = .01266 | reciprocal     |
| DBH            | = 18.0   | inches         |
| L              | = 32.    | feet (sawlogs) |

THE SOLUTION

$$V_t = (237.8) (1.05) (.0245) (.01266)$$

$$\begin{aligned} V_{tcu} &= 6.12 \text{ cubic feet (net)} \\ V_{tcd} &= .077 \text{ cords (net)} \end{aligned}$$

The average Industrial C.F.I. case might use this formula on 5,000 to 10,000 trees. Values on individual trees are not reliable but totals for groups of trees give reliable answers. Converting factors are based on usable length classes in two-foot intervals as top wood volume is not appreciably affected by tree diameter.

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NOTE: Tables of converting factors to be published in future newsletters.